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INFLUENCE OF DIET AND SEX ON THE PERFORMANCE OF
THREE BREEDING GROUPS OF PIGS MARKETING AT
THREE DIFFERENT WEIGHTS

by



PETER JOSEPH SKITSKO

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Influence of Diet and Sex on the Performance of Three Breeding Groups of Pigs Marketed at Three Different Weights" submitted by Peter Joseph Skitsko, B.Sc., B.Ed., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Experiments were designed to study the influence of high and low energy diets under conditions of limit-feeding imposed by allowing pigs access to feed for two, 1 hr periods per day on the performance of three breeding groups of pigs marketed at three different weights. The diets contained approximately 3650 and 2750 kcal digestible energy per kg and had similar ratios of crude protein, lysine, methionine and cystine and calcium to digestible energy. Performance of the pigs was based on average daily gain, average daily feed consumption, feed conversion, digestibility of energy and nitrogen, nitrogen retention and carcass characteristics. A $2 \times 2 \times 2 \times 3 \times 3$ factorial design consisting of two replicates, two diets, two sexes, three breeding groups and three market weights was used in these studies. In addition a $1 \times 2 \times 2 \times 3$ factorial experiment consisting of one breeding group, two diets, two sexes and three market weights was used to study the aforementioned parameters under self-feeding conditions.

The high energy diet significantly improved average daily gain and feed conversion as compared to the low energy diet. However, when converted to the basis of digestible energy in Experiment 1, there were no differences in energetic efficiency between the pigs fed the high and low energy diets. Males had higher average daily feed consumption and, when the high energy diet was fed they had higher average daily gain than females. The males were less efficient converters of feed to gain when the low energy diet was fed but no differences in feed conversion existed between sexes when the high energy diet was fed. A significant difference between breeding groups was found for average

daily gain and feed conversion; the Duroc and Hampshire-sired groups had a higher average daily gain and were more efficient converters of feed to gain than the Yorkshire-sired group.

The digestibility of dietary energy and nitrogen was not affected by sex or breeding group. Nitrogen digestibility was increased when the high energy diet was fed. Nitrogen retention was not affected by diet, sex or breeding group.

Carcasses of pigs receiving the high energy diet were fatter as evidenced by higher dressing percentages, greater total backfat thickness, decreased ratio of loin area to backfat thickness, lean in the ham face, ham as a percent of carcass and Record of Performance (ROP) score. Females were superior to the males in all carcass measurements except dressing percentage where differences were not significant. The Yorkshire-sired group were inferior to the Duroc and Hampshire-sired groups in dressing percentage and loin area but were superior in carcass length. Market weight had a significant effect on carcass characteristics. Dressing percentage, carcass length and loin area were improved with increases in carcass weight while the total backfat thickness, ham as a percent of carcass and ROP score were inferior with increases in carcass weight.

Feeding system had significant effects on average daily gain, average daily feed consumption and feed conversion. Self-fed pigs had higher average daily gains and average daily feed consumption but were less efficient converters of feed to gain. Carcasses of self-fed pigs were inferior to those of limit-fed pigs in total backfat thickness, loin area, ratio of loin area to backfat thickness and ROP score.

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INTRODUCTION

Several workers have shown that the caloric density of a diet plays a major role in controlling the feed intake of several species of animals, including the pig. If digestible energy content of a diet does in fact control the feed intake of the pig, it would be more meaningful to express the nutrient requirements of the pig in terms of the caloric density of the diet rather than as a percentage of the diet.

The ability of different breeds and breeding groups to utilize nutrients is an interesting area which has not been extensively studied. If differences between breeds or breeding groups exist it would be necessary to recognize these differences in nutrient requirements in the formulation of diets.

The detrimental effects of high energy diets on carcass characteristics have been reported by numerous workers. Various combinations of protein and energy have been studied. The influence of high energy and low energy diets on breeding groups and different market weights has not been fully elucidated. The possible effects of these diets on carcass lean to fat ratios is of even greater importance with recent changes in the Canadian grading system.

The studies reported in this thesis were conducted to determine the effects of high energy and low energy diets on two sexes of pigs of three breeding groups marketed at three different weights. The criteria used for evaluation were average daily gain, feed consumption, feed conversion, digestibility of energy and nitrogen, nitrogen retention and carcass characteristics.

LITERATURE REVIEW

A survey of the literature indicates that the productive performance of several species of animals is influenced by the energy-nutrient relationships in the diet. This literature review will be limited mainly to studies conducted with pigs ranging from 20 to 100 kg liveweight as these weight ranges overlap the weights of pigs used in the present study. In some cases, reports of experiments with younger pigs or with other species are included when these seem necessary to clarify a point.

Rate of Gain

Influence of Energy

Much of the research on the effects of energy on average daily gain (ADG) has been carried out in conjunction with studies in which the protein levels of the diets have also varied. Heitman (1950) found that the addition of 5 or 10% stabilized beef tallow to the diet caused significant increases in ADG while lard had no effect on ADG. Sewell, Tarpley and Abernathy (1958) reported that the addition of stabilized prime tallow at levels of 0, 5 and 10% of the diet resulted in increased ADG. Kuryvial, Bowland and Berg (1962), using a 3×3 factorial experiment including three protein levels as well as three energy levels, also reported improved ADG when stabilized fat was added to the diet. Other workers, (Day et al., 1953; Kennington, Perry and Beeson, 1958; King, 1963; Greeley et al., 1964b; Noland and Scott, 1960; Waldern, 1964) have observed increased ADG as

a result of increased energy levels in the diet.

On the other hand, Kropf, Pearson and Wallace (1954) have reported that the addition of 10 or 15% beef tallow did not provide a consistent increase in ADG. Similarly, Mulholland, Erwin and Gordon (1960); Robinson and Lewis (1964); Robinson (1965) found no significant increase in ADG when fat was added to the diet. Lowrey et al. (1962) noted that 10% beef tallow in a 19% protein diet resulted in a non-significant increase in weight gain and that this level of tallow in a 13% protein diet caused a non-significant decrease in weight gain. Standish and Bowland (1967) observed that the addition of 0,4,8 or 12% fat to diets fed to 3 to 9-week-old pigs did not affect their ADG. Hale, Johnson and Warren (1968) also reported that the addition of 4 or 8% tallow to the diet did not affect ADG. Daily digestible energy consumption, as discussed in a later section of this review, may explain most of the inconsistencies among different studies.

Influence of Protein

Protein or essential amino acids fed at sub-optimal levels may inhibit ADG but protein in excess of requirements is unlikely to influence ADG. Abernathy, Sewell and Tarpley (1958) reported that significantly ($P < 0.01$) faster gains were obtained with pigs fed 18% as compared with 14% protein during the growing period (18 to 50 kg). The protein level did not have a significant influence on ADG during the finishing period (50 to 86 kg). Seerley, Poley and Wahlstrom (1964) recorded a 7.4% improvement in ADG for pigs fed a 14.4% protein

diet as compared to a 12.5% protein diet. Young et al. (1968) reported increased ADG during the growth period when the protein level was increased, however, protein levels did not affect ADG in the finishing period. A number of other workers, (Hironaka and Bowland, 1954; Jensen et al., 1955; Pond, Kwong and Loosli, 1960; Kuryvial et al., 1962; Lee, McBee and Horvath, 1967) have observed improved ADG when high protein levels of 17 to 20% as compared to lower levels of 13 to 14% were fed. Wahlstrom (1954) and Boenker, Tribble and Pfander (1960) reported that pigs fed a 10% protein diet during the finishing period made slower gains than pigs fed diets containing higher protein levels.

Greeley, Meade and Hanson (1964a) obtained a highly significant improvement in the conversion of digestible protein (DP) to gain, which was attributable to increased protein levels in the diets. Standish and Bowland (1967) reported a similar observation using 3 to 9-week-old pigs.

In contrast to the previous studies reviewed, Wallace et al. (1954) found that 14.3% protein was as satisfactory as 20.9% protein for weight gains of growing and finishing pigs. Noland and Scott (1960) noted that, when feeding 12, 16 or 20% protein in finishing diets, protein level had no effect on ADG. Previously Catron et al. (1952) reported no difference in ADG up to 34 kg when protein levels varying from 14 to 20% were fed. Hanson, Ferrin and Singh (1955) also observed no difference in ADG when 14, 16 or 18% protein mixtures were fed up to 57 kg liveweight. Holme, Goey and Robinson (1965) found no difference in ADG up to 57 kg when varying protein levels

from 10 to 19.3% were fed. Warden (1951), Hoefer et al. (1952), Wahlstrom (1954), Meade (1956), Kennington et al. (1958), Boenker et al. (1960) and Greeley et al. (1964b) have all reported that protein level in the diet did not affect ADG. Furthermore Mulholland et al. (1960) found that increasing the protein level from 14 to 28% reduced ADG by 86 g per day.

Influence of Energy-Protein Relationships

An energy-protein relationship has been reported by a number of workers. Costain and Morgan (1961) observed that gains of growing pigs were significantly higher when high protein-low energy diets were fed than when high protein-high energy diets were fed. In further studies Robinson, Morgan and Lewis (1964) fed diets containing energy levels of 2640, 2860, 3080 and 3300 kcal digestible energy (DE) per kg and crude protein levels of 14, 16, 18, and 20%. They noted improved gains with high protein levels (20%) when fed in low energy diets containing 2860 kcal DE/kg but not with diets containing 2640, 3080 or 3300kcal DE/kg. However, Sunde (1956) using the chick found that when a high protein-low energy diet was fed a reduction in the growth rate occurred when it was compared to the low protein-low energy group. The addition of fat to this type of diet improved growth.

Lowrey, Pond and Maner (1958) reported that the addition of 10% fat to low protein diets decreased ADG. Similarly Scott, Sims and Staheli (1955) have noted in chick studies, that with low protein levels the addition of fat suppressed growth. Lowrey et al. (1958), Pond et al. (1960) found that the addition of fat to high protein

diets tended to improve ADG.

Clawson, Barrick and Blumer (1956) observed greater increases in ADG with pigs to 34 kg liveweight on a narrow protein-energy ratio than on wider ratios. Clawson et al. (1962) stated that in the first 28 days, ADG was significantly influenced by the calorie-protein ratio with the narrow ratio giving the best results. This difference was not apparent at the time the pigs reached market weight. Clawson (1967) reported that protein and energy influenced ADG independently. Caloric intake was depressed at high energy levels when protein was inadequate or when an amino acid imbalance existed. Matterson et al. (1955) found with chicks that ADG increased as the productive energy to protein ratio decreased from 51:1 to 31:1 with isocaloric diets of 20 to 28% protein.

Influence of Sex

In almost all nutritional studies with swine where sexes are compared, the comparison is between growing females (gilts) and castrate males (barrows), as entire males are not normally used for pork production. Therefore, studies using the entire male will not be included in this review and the term male will refer to a castrate male.

Crampton and Ashton (1945) reported that males grew faster than females with the greatest difference in ADG occurring during the fattening period. Bruner et al. (1958) found that differences in ADG between males and females were significant with the males reaching market weight by 160.1 days and the females by 167.1 days of age.

Crampton (1941), Bennett and Coles (1946), Crampton and Ashton (1946), Jensen et al. (1955), Kennington et al. (1958), Bowland and Berg (1959), Mulholland et al. (1960), Wagner et al. (1963), Hale and Southwell (1967) obtained similar results.

However, Lucas and Calder (1956) using very high (VH), regular (R) and very low (VL) planes of nutrition in various combinations during the growing and finishing periods found no over-all differences in ADG between sexes. In the finishing period the females grew more rapidly than the males when VH:VH or VH:R diets had been fed during the growing and finishing periods, respectively. Bell (1965) also observed that males out-gained females on low protein diets (13%) but showed less advantage when high protein diets were fed. Bowland (1966) reported that males grew more rapidly than females under self-feeding conditions. Charette (1961), Robinson and Lewis (1964), Robinson et al. (1964), Blair and English (1965), Hale et al. (1968) could show no difference in ADG between sexes.

Although conflicting evidence is presented with respect to the effects of energy on ADG, the greater body of evidence supports the contention that high levels of available energy improve ADG. The numerous studies have been conducted using diets varying so widely in digestible or metabolizable energy that it is difficult to compare the results obtained. An energy-protein interrelationship appears to exist since the combination of high energy and low protein in the diet inhibits ADG. Sub-optimal protein levels may also inhibit ADG either independently or in association with high energy in the diet. However, a review of the literature indicates conflicting evidence with respect

to the effects of protein on ADG. It would appear that the protein level is more important during the growing stage than during the finishing stage. Such results would be expected on the basis of requirements for the essential amino acids of pigs at various stages of growth but in much of the literature protein levels per se rather than essential amino acid levels are used for comparison.

Feed Consumption, Feed Conversion (kg feed per kg gain)

Influence of Energy

Dansky and Hill (1951) reported that the chick had a remarkable ability to compensate for reduced caloric density of the feed by increasing feed consumption. Hill and Dansky (1954) in further studies with chicks suggested that the productive energy level of the diet was a major factor in controlling feed intake of chicks. Peterson, Grau and Peek (1954) noted that feed intake within physiological limits was governed by the energy requirements while the protein intake limited the need for more energy by limiting growth. Matterson et al. (1955) reported that as the caloric density of a diet containing a given protein level increased, feed conversion (FC) improved. Scott et al. (1955) also reported that the addition of 7 or 14% animal fat to the diet improved FC.

Sibbald et al. (1957a) observed that weanling rats consumed similar levels of DE per day when fed diets containing 275 to 391 kcal DE/100 g of diet. Sibbald et al. (1957b) also showed that variations in the feed consumption of rats fed varying levels of protein was associated with the DE level of the diet.

In experiments with swine a number of workers (Abernathy et al., 1958; Sewell et al., 1958; and Pond et al., 1960) have noted that an increase in the caloric density of the diet resulted in a decrease in average daily feed (ADF). Hillier (1950), Kropf et al. (1954), Baird, McCampbell and Neville (1958), Sewell and Carmon (1959), Mulholland et al. (1960), King (1963), Greeley et al. (1964b) and Hale et al. (1968) all reported improved FC from the addition of fat to the diet. In contrast to these results Robinson and Lewis (1964) and Robinson (1965) found no significant difference in FC when diets containing different energy levels were fed. As fat contains a higher level of energy than is contained per unit of carbohydrate or protein, an improved FC would be expected when fat supplements are added to the diet. A more meaningful expression is the reporting of DE required per unit of gain as has been done in recent studies, for example Kuryvial et al. (1962).

Influence of Protein

Catron et al. (1952) found that feeding diets varying in protein level had no effect on ADF intake of pigs. Kennington et al. (1958) have reported that the ADF decreased as the fat level increased but that protein had no influence on ADF or FC. Similarly Noland and Scott (1960) indicated that pigs fed low energy diets consumed .34 kg more feed daily while the protein level had no effect on ADF. However, Stevenson, Davey and Hiner (1960) reported that high protein levels resulted in improved FC. Similar results were obtained by Hare, Reynolds and Luther (1956), Bowland et al. (1958), Wagner et al. (1963), Lee et al. (1967), Hale and Southwell (1967) and Young et al.

(1968).

Seerley et al. (1964) noted that increased levels of fat improved ADF and FC. An average of 5.7% and 10.7% less feed was consumed by pigs fed medium and high energy diets, respectively, as compared to low energy diets. Protein exerted little influence on ADF but high energy-high protein diets were utilized 11% more efficiently than high energy-low protein diets.

Clawson et al. (1956) found little difference in FC associated with differences in the calorie-protein ratio. Investigations by Boenker et al. (1960) indicated that the calorie-protein ratio had no effect on FC. From weanling to 57 kg liveweight, FC improved significantly ($P < 0.01$) with increases of energy levels in the diet but protein had little influence on FC. Clawson et al. (1962), however, reported that ADF was influenced by the calorie-protein ratio of the diet.

Bowland and Berg (1959) reported that protein level had no effect on ADF but high protein levels alone or in combination with high energy levels improved FC in the finishing period. Costain and Morgan (1961) also reported significantly ($P < 0.05$) improved FC with high protein diets.

Influence of Sex

Clawson et al. (1962) noted that males ate significantly more than females (2.73 vs. 2.61 kg/day). Bowland (1966) reported that males had a higher ADF than gilts when pigs were self-fed during the finishing period. Blair and English (1965) observed that the over-all

feed intake was 5.9% (significant at $P < 0.01$) lower and the FC 6.1% better in the female than in the male. Bowland and Berg (1959), Charette (1961), Smith, King and Gilbert (1962), Hale et al. (1968) reported that females were more efficient feed converters than males while Robinson and Lewis (1964), Robinson et al. (1964) and Young et al. (1968) found no sex differences with respect to FC.

Several workers (Lucas and Calder, 1956; Robinson, 1965) have observed that the FC of the female on a low energy diet was inferior to the male while the FC on high energy diets was superior to the male. Blair and English (1965) noted that up to 55 kg liveweight the FC of males was 7.3% lower (significant at $P < 0.01$) while from 55 kg to 89 kg the ADF was 9.2% lower, significant at ($P < 0.01$) and FC 5.2% better in the female. Plank and Berg (1963) observed that on equalized feed intake, females made more efficient use of feed for body weight gains while on liberal feeding males and females were equal in FC.

The evidence presented indicates that the caloric density of the diet is of major significance in controlling the feed intake of several species of animals, including the pig. The feeding of diets high in digestible energy tends to decrease ADF and improve FC. Dietary protein on the other hand appears to have little effect on ADF and FC. However, an energy-protein interaction appears to exist in that high energy-high protein diets are more efficiently utilized than high energy-low protein diets. Sex differences also appear to influence feed intake and FC with the majority of evidence indicating that males consume more ADF and are less efficient in FC than females.

Energy and Nitrogen Digestibility and Nitrogen Retention

Forbes et al. (1946a) concluded that the addition of fat to the diet had no effect on the DP or nitrogen (N) retention of rats fed these diets. Forbes et al. (1946b) also reported similar results when rats were fed an above maintenance diet but in this case there was a slight decrease in N retention with increasing levels of fat in the diet. Sibbald, Berg and Bowland (1956) concluded that the DE intake influenced the N retention of weanling rats with higher DE diets increasing the amount of N retained. Sibbald et al. (1957b) found that N retention was controlled by the ratio of DE per g of digestible N in the diet. French (1948) noted that a reduction in protein level brought about a decrease in N retention while Calloway and Spector (1955) observed that the urinary N excretion of adult rats became progressively greater as the energy level of the diet was reduced.

In swine studies, Greeley et al. (1964a) reported that neither level nor source of fat significantly affected protein digestibility while there was a highly significant ($P < 0.01$) trend toward reduced efficiency of protein digestion with increasing dietary protein levels. The DP increased with increasing protein content as did the DE.

Asplund, Grummer and Phillips (1960) observed that when 10 and 20% stabilized grease was added to the diets of 8-week-old pigs the apparent digestibility of ether extract and protein increased. Lowrey et al. (1958) found that fat, added to the diet of the young, growing pig, resulted in increased DP. Bowland et al. (1958) also reported improved N digestibility and N retention but a slight decrease in DE

with the addition of fat to the diet. Kuryvial and Bowland (1962) found that an increase in the energy level increased the DP but did not improve N retention.

In contrast, Lowrey et al. (1962) observed that the addition of fat to the diet had no effect on DP. Lowrey et al. (1963) further found that the DP was not affected by protein source or energy level in the diet and that increased dietary energy had no effect on N retention.

The protein level in the diet also appears to affect DP. Likuski, Bowland and Berg (1961) reported an increase in percentage DP with high protein levels. However, the retention of digested N was reduced with higher energy levels as compared to lower energy diets. Holme et al. (1965) noted that N balance studies had indicated that the pigs on the highest level of protein retained more N per kg body weight than pigs on the lower levels. Robinson et al. (1964) reported a decrease in N retention on high protein diets which was accentuated by high energy diets as the pigs matured. Pigs fed low protein showed lower N retention with no decrease observed with increased liveweight.

There are numerous conflicting reports concerning the effects of energy on DP and definite conclusions cannot be drawn. However, there does appear to be a trend toward reduced protein retention with increased energy with a concomitant improvement in DE when high levels of fat are included in the diet. There also appears to be a reduced efficiency of DP with increasing protein levels while there are conflicting reports concerning the effect of dietary protein on

N retention. In general the percentage N retention at a given level of dietary protein will decrease as the pig becomes heavier and its requirements for protein (essential amino acids) per unit of feed intake become lower.

Carcass Characteristics

Influence of Energy

Heitman (1956) reported that the addition to the diet of 5 and 10% stabilized lard significantly ($P < 0.01$) increased backfat thickness. Similar increases in backfat thickness with the addition of fat to the diet, resulting in increased digestible energy content of the diet, have been noted by various workers (Kennington et al., 1958; Sewell et al., 1958; Mulholland et al., 1960; Kuryvial et al., 1962; Wagner et al., 1963; Seerley et al., 1964). Reports contradicting the aforementioned observations have indicated that the addition of fat to the diet does not significantly affect the average backfat thickness (Day et al., 1953; Kropf et al., 1954; Abernathy et al., 1958; Sewell and Carmon, 1959; and Pond et al., 1960). Several groups of workers (Noland and Scott, 1960; Likuski et al., 1961; Robinson and Lewis, 1964) have observed increased backfat thickness and increased total fat in the carcass with the addition of fat to the diet. Mulholland et al. (1960) and Wagner et al. (1963) have reported a decrease in the yield of lean cuts attributable to the addition of fat to the diet. The use of high energy levels in the diet has been reported to increase the dressing percentage (carcass weight/liveweight) of the carcass (Bowland and Berg, 1959; Kuryvial et al., 1962; Wagner

et al., 1963; Greeley et al., 1964b; and Hale et al., 1968).

Influence of Protein

Several groups of workers (Wilson et al., 1953; Ashton et al., 1955; Beacom, 1959; Bowland and Berg, 1959; Morgan et al., 1959; Mulholland et al., 1960; Seerley et al., 1964; Robinson, 1965; Lee et al., 1967; and Young et al., 1968) have reported that feeding high protein diets may result in leaner carcasses. Bowland and Berg (1959) also reported that high protein levels in the diet reduced average backfat thickness and these observations have been confirmed (Boenker et al., 1960; Stevenson et al., 1960; Kuryvial et al., 1962; Nielsen et al., 1963; and Hale and Southwell, 1967). A number of reports (Wahlstrom, 1954; Seerley et al., 1964; Hale and Southwell, 1967; Young et al., 1968) have indicated an increase in the loin area with increased protein levels. Loin eye area (cross-sectional area of the longissimus dorsi muscle at the 14th rib) is considered to be a reasonable indicator of lean content in a carcass (Fredeen et al., 1964).

In contrast to the above reports, Wahlstrom (1954) and Kennington et al. (1958) reported no significant effects of protein level on average backfat thickness. Catron et al. (1952) noted that no significant differences existed among varying levels of dietary protein with respect to backfat thickness, body length or depth, and percentage of lean in the carcass. Bowland and Berg (1959), Aunan, Hanson and Meade (1961), Clawson et al. (1962), Greeley et al. (1964b) and Waldern (1964) all indicated that dietary protein levels had no

significant effect on carcass characteristics.

It was reported by Bowland and Berg (1959) that neither protein nor energy levels in the diet had any effect on carcass length. However, Noland and Scott (1960) observed that pigs fed 16 or 20% protein had significantly ($P < 0.01$) longer carcasses as compared with those fed 12% protein.

Influence of Sex

The female swine carcass has been reported to have less thickness of backfat than does the male carcass (Crampton and Ashton, 1945; Bennett and Coles, 1946; Bruner et al., 1958; Kropf et al., 1959; Charette, 1961; Wagner et al., 1963; Greeley et al., 1964b; Waldern, 1964; Hale and Southwell, 1967; and Young et al., 1968). A number of workers (Crampton and Ashton, 1945; Bennett and Coles, 1946; Lucas and Calder, 1956; Self, Bray and Reiersen, 1957; Hale and Southwell, 1967; Hale et al., 1968; and Young et al., 1968) have also observed that the female carcass is superior to the male carcass in length. Charette (1961) reported no difference in length between sexes while Bowland and Berg (1959) stated that the female carcass was superior to that of the male in all respects except length where differences were non-significant.

Crampton and Ashton (1945), Bennett and Coles (1946), Lucas and Calder (1956), Self et al. (1957), Bruner et al. (1958), Wallace et al. (1959), Charette (1961), Greeley et al. (1964b), Waldern (1964) and Young et al. (1968) have all noted that the female carcass had a larger loin area than did the male carcass. Salmela, Rempel and

Gates (1963), Robinson and Lewis (1964), Robinson et al. (1964) and Robinson (1965) have reported that the female carcass was superior to that of the male in all respects.

In summary, high energy diets under self-feeding conditions or other feeding methods that do not equalize digestible energy intake appear to have deleterious effects on carcass characteristics in that they increase the backfat thickness and decrease the yield of lean cuts from the carcass as compared to lower energy diets. High energy levels in the diet have been reported to improve the dressing percentage of the carcass thus reflecting the higher fat content of the carcass from pigs so fed. Increasing dietary protein tends to produce a leaner carcass with reduced average backfat thickness and an increased loin area. The female carcass is usually leaner than that of the male. This is indicated by reduced backfat thickness and increased loin area in females as compared to males at market weight. The female carcass also tends to be longer than the male carcass.

Effects of Breeds and Breeding Groups on Gain, Feed Conversion and Carcass Characteristics

Hess et al. (1941) provided evidence to demonstrate that FC in chickens is inherited. They found that the least efficient line required 21% more feed per unit gain than the most efficient line of birds to 8 weeks of age. McCartney and Jull (1948) also reported a significant difference in FC to 10 weeks of age between two different strains of New Hampshire chickens.

Lucas and Calder (1956) in swine studies reported relative

differences in FC and backfat thickness when different breeds were fed varying levels of nutrition. Salmela, Rempel and Comstock (1960) found a significant breed $\times$ level of feeding interaction for ADG at 200 days of age. Similarly, Aunan et al. (1961) noted that breed had a significant ($P < 0.01$) effect on ADG. King (1963) also found significant ($P < 0.05$) breed differences for ADF. Plank and Berg (1963) reported that sire group differences in feedlot performance reached statistically significant ($P < 0.01$) levels for ADG and significant ($P < 0.05$) levels for FC. They also noted that carcass differences between sire groups were significant for carcass length ($P < 0.01$), average backfat thickness ($P < 0.05$) and ROP score ($P < 0.01$).

EXPERIMENTAL

Objectives

The principal objectives of the experiments were to study the effects of high and low energy diets, formulated to maintain similar ratios of calcium, lysine, methionine and cystine to digestible energy, and fed to either Yorkshire × Yorkshire, Hampshire × Yorkshire or Duroc × Yorkshire pigs. The study was conducted from an initial weight of 23 kg to market weight at either 68, 91 or 114 kg liveweight using the following parameters:

- 1) Rate of gain, feed consumption and feed conversion during the growing and finishing periods.
- 2) Apparent digestibility of nitrogen and energy and nitrogen retention measured at 45 kg liveweight.
- 3) Carcass quality as measured by ROP score, total backfat thickness (based on three measurements at the shoulder, back and loin) dressing percentage, carcass length, percent lean in the ham face, ham as a percent of carcass, loin area (area of longissimus dorsi muscle at 14th rib), and ratio of loin area to backfat thickness.

Experimental Design

1) Introduction

In Experiment 1, two replicates were conducted at The University of Alberta Livestock Farm. Replicate 1 was conducted during 1967-1968; however, the data is included as part of this thesis. Replicate 2 was conducted by the author during 1968-1969. Both replicate 1 and 2

included two diets, two sexes, three breeding groups and three market weights, under limit-feeding conditions. The limit-feeding was accomplished by allowing the pigs access to feed for two 1 hr periods per day which based on previous observations (Bowland, 1966) would result in a feed intake restriction as compared to continuous access to self-feeders. In addition in Experiment 2, 24 pigs were self-fed in conjunction with replicate 2 of Experiment 1. The factors studied were two diets, one breeding group, namely the Hampshire × Yorkshire group and three market weights. The data from the later experiment were compared with the performance data from the corresponding breeding group in replicate 2. Digestibility and metabolism experiments (Experiment 3) were also carried out with two groups corresponding to the replicates discussed above.

2) Methods and Procedures

In all experiments the pigs were identified within 12 hr of birth by ear notching and the "black" teeth were removed. The pigs were also treated for anemia prevention by the injection of a 2 ml dose of Imposil 200 (containing 100 mg of iron per ml)¹ at 4 days of age. Male pigs were castrated at 2 weeks of age. The pigs were treated with lindane (gamma isomer of benzene hexachloride) to prevent skin parasites. At approximately 8 weeks of age the pigs were vaccinated

¹Cyanamid of Canada Ltd., Agricultural Products, Montreal, P.Q.

with 5 ml of erysipelas bacterin¹ to protect against erysipelas.

All pigs were weaned at 3 weeks of age and fed the regular University of Alberta starter diet until they were placed on trial at an average weight of 23 kg and an average age of 74 days. At this time they were fed the experimental diets, which are outlined below.

Pigs from each of the three breeding groups were assigned at random on the basis of sex to the two diets and three market weights.

3) Formulation of Experimental Diets

The formulation and composition of the diets fed are given in Table 1. The high energy (HE) and low energy (LE) diets were formulated to maintain the same ratio between total crude protein and digestible energy (53 g protein per 1,000 kcal digestible energy) in each diet. The diets were also formulated to maintain similar ratios of lysine, methionine, cystine and calcium to digestible energy. However, relative ratios of phosphorus were not maintained as the two diets contained similar levels of phosphorus. A considerable portion of phosphorus in the LE diet came from wheat bran in which phosphorus availability is generally low.

All diets were ground, mixed and bagged at The University Livestock Farm elevator and stored in the Muttart² swine barn where Experiment 1 was conducted.

¹Agricultural Division, Chas. Pfizer and Co. Inc., New York, N.Y.

²The terms Muttart barn, New barn and L barn are used for convenience to identify the barns at The University of Alberta Livestock Farm that are commonly called by these names.

Table 1. Formulation and composition of diets.

Diet	HE	LE
<u>Ingredients, %</u>		
Wheat	60.3	9.88
Oats	8.8	47.5
Wheat bran		32.3
Stabilized tallow	8.0	2.0
Soybean meal (44%)	12.0	3.0
Fishmeal (herring, 72%)	6.0	3.0
Meat meal	3.0	1.0
Iodized salt	0.5	0.4
Ground limestone	0.5	0.6
Dicalcium phosphate	0.5	
Zinc sulphate	0.05	0.04
Trace mineral mix ¹	0.10	0.08
Vitamin B-complex mix ²	0.15	0.12
Vitamins A and D ³	+	+
Aurofac-10 ⁴	0.10	0.08
<u>Composition</u>		
<u>Calculated</u>		
Digestible energy kcal/kg	3780	2950
Protein %	20.1	15.5
Ratio for DE	1.0	0.77
Ratio for total protein	1.0	0.77
Lysine %	1.05	0.77
Methionine and cystine %	0.66	0.50
Calcium %	0.81	0.60
Phosphorus %	0.67	0.68
<u>Actual (by analysis)</u>		
Digestible energy kcal/kg	3652	2757
Protein %	19.9	15.3
Ratio for DE	1.0	0.75
Ratio for total protein	1.0	0.78

¹Contains the following minerals per kg of mineral mix: cobalt carbonate, 2.28 g; copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), 24.50 g; ethylene diamine dihydroiodide, 1.30 g; ferrous carbonate, 234.80 g; manganous oxide, 47.73 g; zinc oxide, 2.96 g; ground limestone, 686.43 g.

²Contains the following B vitamins per kg of vitamin mix: riboflavin, 4.4 g; pantothenic acid, 8.8 g; niacin, 19.8 g; choline chloride, 22.0 g; folic acid, .66 g.

³To supply 220,000 I.U. vitamin A and 44,000 I.U. vitamin D per 100 kg of diet.

⁴Contains 22 g Chlor tetracycline hydrochloride/kg of mix.

Feeding Experiments

In Experiment 1, a total of 144 pigs were involved in the two replicates. They were individually fed for two, 1 hr periods daily starting at 7:00 a.m. and 4:00 p.m. When not being fed, they were together in groups of four pigs. Each group of four pigs was housed in a 6.0 m $\times$ 2.5 m pen with a solid concrete floor. This area also included four individual feeding stalls, each 2.0 m long and 0.6 m wide. Water was available to the pigs except when they were being fed. The pigs were weighed weekly and individual feed consumption was recorded.

For the self-feeding study, Experiment 2, 24 pigs were individually housed in the New barn at The University of Alberta Livestock Farm in 1.2 m $\times$ 1.2 m pens with half-slotted concrete floors. Feed and water were available at all times and individual feed consumption records were kept. The pigs assigned to the 114 kg market weight were moved to the L barn at an average weight of 63 kg. These pigs were housed in groups of two, in pens 2.6 m long and 1.8 m wide with a solid concrete floor. Sexes were separated. Data from this study was compared with the Hampshire-sired breeding group in replicate 2 of Experiment 1.

Digestibility and Metabolism Studies - Experiment 3

At approximately 45 kg liveweight two males and two females from each dietary group and each breeding group, from both replicates of Experiment 1, were removed from their pens and placed in the metabolism cages described by Castell (1967).

The pigs were allowed 3 days to become accustomed to the cages, after which time, the pigs were removed and the cages cleaned with water. Each pig was then returned to its cage for a 72 hr collection period. During the collection period a total collection of feces and urine was made. The daily feed allowance was based on the individual feed consumption of the previous week. The feed was given in equal quantities at 7:00 a.m. and 4:00 p.m. each day. Water was available at all times.

The feces were removed from the screen following the morning and evening feeding each day. The feces were weighed and then stored at 3 C until the completion of the trial. Following the completion of the trial the feces were mixed and a 50 g wet sample was taken for nitrogen determination. The remainder of the feces was weighed, air dried in a forced air oven¹ at 60 C for 48 hr, equilibrated with the humidity in the air for another 48 hr, weighed, ground through a Size 8, C and N Laboratory Mill² to pass through a 2 mm mesh screen, and stored in a sealed container for energy determination.

Urine was collected in a 12 liter plastic container which contained approximately 25 ml of 25% H₂SO₄ (v/v). The volume of the acidified urine was measured in a 2000 ml graduated cylinder, a 250 ml aliquot was placed in a glass-stoppered bottle and the sample stored at 3 C until analyzed for energy and nitrogen. The urine was prepared for energy determination by placing it in the freeze dryer³ for a

¹Style V 31, Despatch Oven Co., Minneapolis, Minn., U.S.A.

²Christy and Norris Ltd., Chelmsford, England.

³Thermovac Model:FD-64 Freeze Dryer, Thermovac Industries Corp., 41 Decker St., Copiague, L.I., N.Y., 11726.

period of 48 hr, then stored in an air-tight container until analyzed.

There were some differences between replicate 1 and replicate 2 with regard to collection technique and method of feeding. In replicate 1 the feces were collected at the end of the test period, then dried in a forced air oven, equilibrated with the humidity in the air, as previously described, weighed and samples taken for nitrogen and energy determination. During the metabolism trial pigs in replicate 1 were self-fed which differed from the feeding system utilized in replicate 2. All other procedures were as previously described.

Methods of Chemical Analysis

The gross energy of the feed, feces and urine was analyzed using an Oxygen Bomb Calorimeter¹. Nitrogen analysis of the feed, feces and urine was done by the Kjeldahl method for nitrogen (AOAC; 1965). A commercial "Kel-Pak"² was used to supply the required amount of catalyst and boric acid was used to retain the ammonia. Crude protein was calculated by applying the conversion factor of 6.25 to the value obtained for nitrogen.

Methods of Statistical Analysis

All weights of pigs and feed consumption were recorded in pounds and then converted to the metric system using the conversion factors,

¹Parr Instrument Company, Moline, Illinois. Temperature changes registered by a Brown Electronik Recorder manufactured by Minneapolis-Honeywell Regulator Company, Philadelphia, Pennsylvania.

²Matheson Scientific, East Rutherford, New Jersey. Supplies Hg catalyst, K_2SO_4 and $CuSO_4$.

1 lb equals 454 g and 2.2 lb equals 1 kg. Rate of gain and feed consumption were statistically analyzed using the pound values and the mean squares obtained have been divided by a factor of $4.84(2.2)^2$ to convert them to the metric system.

The data was analyzed statistically with the aid of the IBM 360 model 67 computer using the analysis of variance program CS017 (Easton, 1967). A composite error term was used in the analysis of variance. The sums of squares for all fourth-order interactions and residual were summed to arrive at the composite error.

Missing data was replaced by the average value of the group from which the data was missing. This was considered a better estimate than any which could be arrived at by the use of a missing value formula¹ and in the analysis of variance, error degrees of freedom were reduced by one for each missing value. Growth and feed data was missing for five pigs and carcass data was missing for seven pigs in Experiment 1. Growth data and carcass data was unavailable for two pigs in Experiment 2.

Differences between means were obtained with the use of Duncan's new multiple range test (Steel and Torrie, 1960).

¹Dr. R.T. Hardin, personal communication.

RESULTS AND DISCUSSION

Experiment 1 - Effects of Diet, Sex, Breeding Group and Market Weight on the Performance of Limit-Fed Pigs

1) Daily Gain, Daily Feed and Feed Conversion

The means for ADG, ADF and FC are given in Table 2 and the mean squares obtained by analysis of variance of the data are given in Appendix Table 1.

(a) Daily gain

Pigs fed the HE diet gained more rapidly ($P < 0.01$) than the pigs fed the LE diet. This difference existed at each market weight and also in the total period for all pigs. Kuryvial et al. (1962), King (1963) and Waldern (1964) have also obtained increased ADG as a result of increased energy levels in the diet.

On the basis of the complete analysis, males gained more rapidly ($P < 0.01$) than females at each market weight and for the total period, with no breeding group differences being evident. These results are in agreement with Bruner et al. (1958), Mulholland et al. (1960) and Wagner et al. (1963), all of whom observed that males grew more rapidly than females but contradicts those of Robinson and Lewis (1964), Blair and English (1965) and Hale et al. (1968) who reported no difference in ADG attributable to sex. A significant sex $\times$ diet interaction occurred in the over-all period (Table 3A). On the HE diet the males gained more rapidly than the females while there was no sex difference on the LE diet.

Breeding groups also influenced ADG with the Duroc and Hampshire-

Table 2. Effect of diet, sex, breeding group and replicate on average daily gain, average daily feed and feed conversion at three market weights - Experiment 1.

	No. of pigs	68 kg			91 kg			114 kg			Total period		
		market weight			market weight			market weight			market weight		
		ADG	ADF	FC	ADG	ADF	FC	ADG	ADF	FC	ADG ¹	ADF ¹	FC ¹
		kg	kg	kg/kg	kg	kg	kg/kg	kg	kg	kg/kg	kg	kg	kg/kg
Replicates 1 & 2	144	.64	1.78	2.89	.67	2.00	3.08	.66	2.26	3.47	.66	2.01	3.15
Diet													
HE	72	.76	1.85	2.46	.75	1.96	2.62	.75	2.26	3.03	**	n.s.	**
LE	72	.52	1.71	3.32	.58	2.04	3.55	.57	2.25	3.92	.76	2.02	2.70
											.56	2.00	3.60
Sex													
M	72	.66	1.85	2.92	.68	2.09	3.21	.67	2.36	3.58	**	**	**
F	72	.62	1.70	2.86	.65	1.91	2.95	.65	2.15	3.37	.67	2.10	3.24
											.64	1.92	3.06
Breeding groups													
D x Y	48	.64	1.73	2.78	.68	2.01	3.07	.70	2.28	3.30	**	n.s.	**
H x Y	48	.68	1.81	2.77	.67	1.99	3.00	.65	2.24	3.48	.68 ^a	2.01	3.05 ^a
Y x Y	48	.60	1.80	3.12	.64	1.99	3.18	.64	2.25	3.63	.67 ^a	2.01	3.08 ^a
											.62 ^b	2.01	3.31 ^b
Replicate													
1	72	.64	1.78	2.87	.66	1.97	2.98	.69	2.30	3.41	n.s.	n.s.	*
2	72	.64	1.78	2.92	.67	2.02	3.18	.64	2.21	3.53	.66	2.02	3.09
											.65	2.00	3.21

¹Any means in a group of factor means having the same superscript are not significantly (P < 0.05) different from each other. The total period includes all pigs from the 3 market weights.

*Significant at P < 0.05.

**Significant at P < 0.01.

n.s. non-significant.

Table 3A. Interaction of diet and sex on average daily gain (kg) - Experiment 1.

Sex	Diet ¹	
	HE	LE
Male	.79 ^a	.56 ^c
Female	.72 ^b	.56 ^c

Table 3B. Interaction of diet and breeding group on average daily feed (kg) - Experiment 1.

Breeding group	Diet ¹	
	HE	LE
Duroc	2.08 ^{ab}	1.93 ^c
Hampshire	2.02 ^{bc}	2.00 ^{bc}
Yorkshire	1.96 ^{bc}	2.06 ^{bc}

Table 3C. Interaction of diet and sex on feed conversion (kg feed/kg gain) - Experiment 1.

Sex	Diet ¹	
	HE	LE
Male	1.24 ^a	1.71 ^c
Female	1.22 ^a	1.56 ^b

¹Any means in a group of factor means having the same superscript are not significantly (P < 0.05) different from each other.

sired pigs gaining more rapidly ($P < 0.01$) than the Yorkshire-sired group. This result is in general agreement with Salmela et al. (1960) and Plank and Berg (1963), who all reported breed differences for ADG.

(b) Daily feed consumption

No significant differences existed between the HE and LE diets with respect to ADF consumption. This data is in conflict with the observations of Abernathy et al. (1958), Sewell et al. (1958), and Pond et al. (1960), all of whom noted that an increase in the caloric density of the diet resulted in a decrease in ADF. A diet $\times$ market weight interaction was significant ($P < 0.05$) with the pigs on the HE diet consuming more feed than the pigs on the LE diet, during the 68 kg market weight period. This difference in ADF was not significant at the 91 kg or the 114 kg market weight. Method of feeding should be noted here as having a possible influence.

Males ate more ($P < 0.01$) than females, which agrees with the findings of Clawson et al. (1962) and Blair and English (1965).

Breeding groups did not differ in their ADF consumption in the total period. This observation is in conflict with that of King (1963) who found significant ($P < 0.05$) breed differences for ADF. However, the breeds used by King in the crosses studied were different from these used in the present study. Possibly breed differences accounted for this discrepancy in ADF. The breeding group $\times$ market weight interaction was not significant. However, the breeding group $\times$ diet interaction was significant ($P < 0.05$) with the Duroc-sired pigs on the HE diet consuming more feed per day than did the Duroc-sired pigs on

the LE diet (Table 3B). This difference was not found to be significant in the Hampshire and Yorkshire-sired breeding groups.

Market weight had an effect on ADF with the 114 kg market weight pigs consuming more feed per day ($P < 0.01$) than did the 91 kg market weight pigs, who in turn consumed more feed per day than did the 68 kg market weight pigs. This indicates that the ADF intake increases with an increase in body weight within the weight ranges involved in this study.

Table 4. Energetic efficiency of pigs fed high and low digestible energy diet - Experiment 1.

Diet	DE per kg gain (Mcal)
HE	9.86
LE	9.92

(c) Feed conversion

Diet had an effect on FC. The pigs fed the HE diet consumed an average of .90 kg less feed per kg gain than did the pigs fed the LE diet ($P < 0.01$). This data is in agreement with Mulholland et al. (1960), Greeley et al. (1964b) and Hale and Warren (1968) and others, all of whom noted improved FC when caloric density was increased by the addition of fat to the diet. When converted to the basis of digestible energy using the data from the digestibility studies reported later there were no differences in energetic efficiency between the pigs fed the HE and LE diets (Table 4).

Females were more efficient ($P < 0.01$) in FC requiring .18 kg less feed per kg gain than did the males. This is in agreement with the findings of Bowland and Berg (1959), Charette (1961) and Hale, Johnson and Warren (1968). However, these data are in conflict with the reports of Robinson and Lewis (1964), Robinson et al. (1964) and Young et al. (1968) who found no sex differences with respect to FC. A diet $\times$ sex interaction was present with the males fed the LE diet being less efficient converters of feed to gain than were the females fed the LE diet (Table 3C) while there were no differences between sexes in FC on the HE diet.

A significant sex $\times$ diet $\times$ market weight interaction was observed (Figure 1). On the LE diet the females were more efficient in FC than were the males. This advantage was maintained at each market weight. On the other hand there were no sex differences at the 68 kg market weight when the HE diet was fed. However, the males were more efficient feed converters at the 91 kg market weight but became less efficient than the females at the 114 kg market weight.

Breeding groups also differed in FC with the Duroc and Hampshire-sired groups being more efficient ($P < 0.01$) than the Yorkshire-sired group. Plank and Berg (1963) reported sire group differences in feedlot performance when the parameter of FC was studied.

2) Carcass characteristics

The means for the carcass characteristics are given in Table 5 while the mean squares obtained by analysis of variance of the data are given in Appendix Table 1.

Pigs fed the HE diet had 3.5% higher dressing percentage ($P < 0.01$) than the pigs fed the LE diet. These results are in agreement with the reports of Bowland and Berg (1959), Kuryvial et al. (1962) and Wagner et al. (1963), who all found that the use of HE levels in the diet increased the dressing percentage. Pigs fed the HE diet also had increased backfat thickness ($P < 0.01$). Kennington et al. (1958), Mulholland et al. (1960) and Seerley et al. (1964) found increased backfat thickness with HE diets. However, Day et al. (1953), Abernathy et al. (1958) and Pond et al. (1960) could find no significant effect of dietary energy on backfat thickness. Also diet affected the ratio of loin area to total backfat thickness with the LE diet yielding the higher ratio ($P < 0.01$). The carcasses from pigs fed the LE diet were also superior ($P < 0.01$) to those fed the HE diet in lean in the ham face, ham as a percent of carcass and ROP score. Diet did not have a significant effect on length or loin area.

Sex had no significant effect on dressing percentage. The female carcasses were longer ($P < 0.05$) than the male carcasses. This data is in agreement with the observations of Self et al. (1957), Hale and Southwell (1967) and Young et al. (1968). The female carcasses had less total backfat ($P < 0.01$) than did the male carcasses. Kropf et al. (1959), Greeley et al (1964b), Waldern (1964) and Hale and Southwell (1967) have reported similar results. The female carcass was also significantly ($P < 0.01$) superior to the male carcass with respect to loin area, ratio of loin to total backfat, lean in the ham face, ham as a percent of carcass and ROP score. Charette (1961), Waldern (1964) and Young et al. (1968) have all found that the female

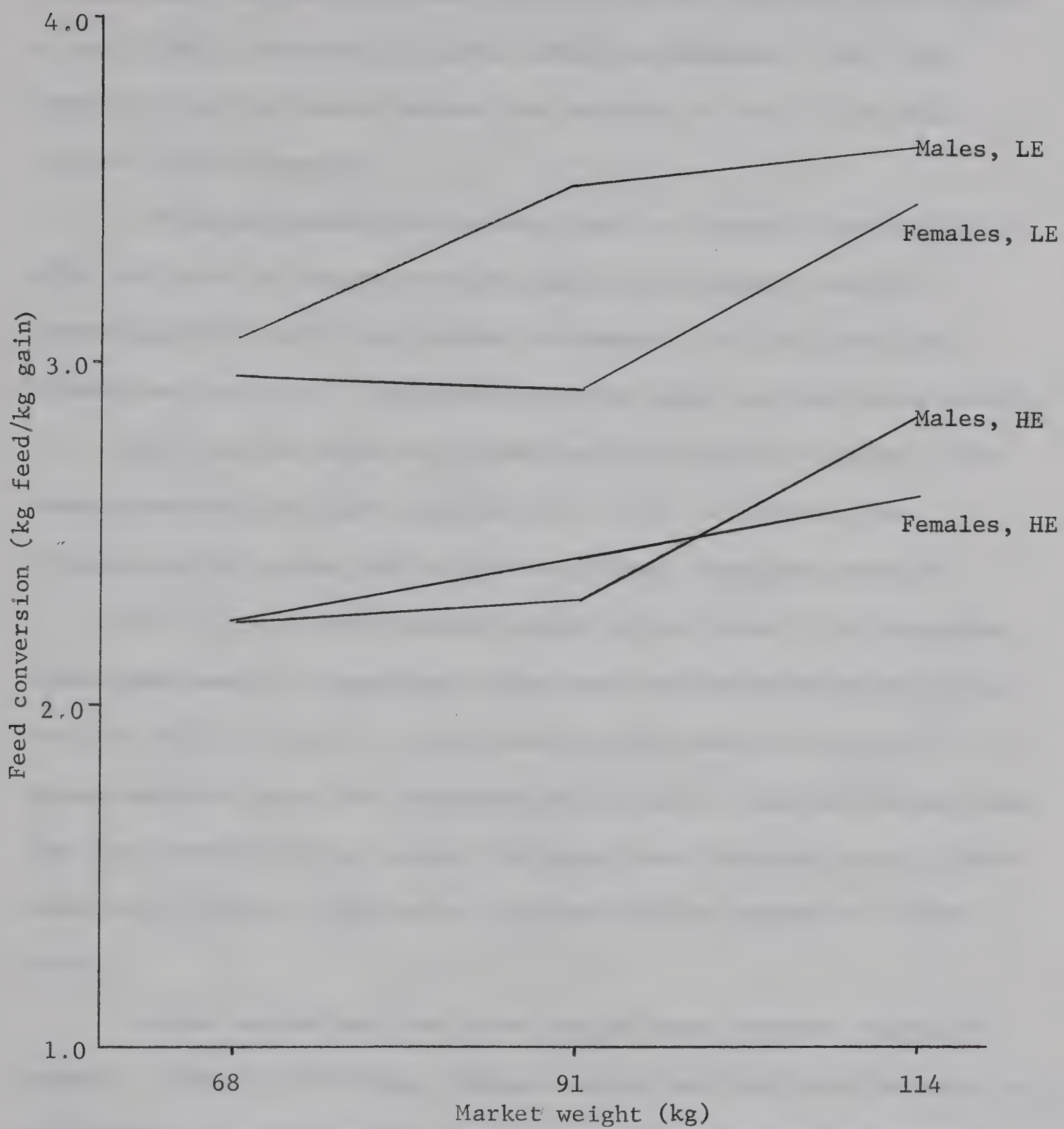


Figure 1. Interaction of sex, diet and market weight on the feed conversion of pigs marketed at three different live-weights - Experiment 1.

carcass had a larger loin area than did the male carcass while Salmela et al. (1963), Robinson and Lewis (1964) and Robinson (1965) have reported that the female carcass was superior to that of the male carcass in all respects.

Breeding groups also had an effect on carcass characteristics with the Duroc and Hampshire-sired pigs having higher dressing percentages ($P < 0.01$) and shorter carcasses ($P < 0.01$) than the Yorkshire-sired pigs. The Hampshire-sired group had less total backfat ($P < 0.05$) than the Duroc and Yorkshire-sired group. Similarly, the Hampshire-sired group was superior ($P < 0.01$) to the Duroc and Yorkshire-sired groups, while the Duroc-sired group was superior ($P < 0.01$) to the Yorkshire-sired group in loin area. The Hampshire-sired group was also superior to the Duroc and Yorkshire-sired groups when the ratio of loin to total backfat thickness was compared. The Hampshire-sired group had a greater percentage of lean in the ham face than the Yorkshire-sired group. No significant breeding group differences were found for the ham as a percent of the carcass or in ROP score.

Market weight was also found to influence carcass characteristics. Dressing percentage, carcass length and loin area improved with an increase in market weight. An increase in market weight brought about a significant increase in total backfat thickness. Market weight had no significant effect on the ratio of loin to total backfat thickness. Market weight, however, did have an effect on the ham as a percent of the carcass and ROP score ($P < 0.01$) with the 68 kg market weight pigs being superior to the 91 kg market weight pigs, who in turn

Table 5. Effect of diet, sex, breeding group and market weight on certain carcass characteristics - Experiment 1.

	Dressing ¹ %	Length ¹ cm	Total ^{1,2} backfat cm	Loin ¹ area sq.cm	Ratio loin to backfat ¹	Lean in ham ¹ face %	Ham/ ¹ carcass %	ROP ¹ score
Replicates 1 & 2	77.6	77.4	9.8	28.4	3.02	50.2	27.5	78.0
Diet								
HE	**	n.s.	**	n.s.	**	**	**	**
LE	79.4	77.3	10.7	27.8	2.69	48.2	27.0	76.3
	75.9	77.6	8.9	28.9	3.35	52.0	28.1	79.7
Sex								
M	n.s.	*	**	**	**	**	**	**
F	77.5	76.9	10.5	26.8	2.67	47.7	27.2	76.6
	77.7	77.9	9.1	29.9	3.36	52.6	27.8	79.4
Breeding group								
D x Y	**	**	*	**	**	*	n.s.	n.s.
H x Y	78.3 ^a	76.1 ^a	9.9 ^a	28.6 ^a	2.97 ^a	50.7 ^{ab}	27.6	77.8
Y x Y	77.8 ^a	76.5 ^a	9.4 ^b	30.2 ^b	3.29 ^b	51.4 ^a	27.5	78.5
	76.7 ^b	79.6 ^b	10.1 ^a	26.3 ^c	2.79 ^a	48.4 ^b	27.5	77.7
Market weight								
68 kg	**	**	**	**	n.s.	**	**	**
91 kg	75.3 ^a	71.5 ^a	8.1 ^a	23.6 ^a	3.07	52.5 ^a	28.3 ^a	81.1 ^a
114 kg	77.2 ^b	77.5 ^b	9.6 ^b	28.6 ^b	3.06	49.7 ^b	27.4 ^b	78.2 ^b
	80.4 ^c	83.2 ^c	11.7 ^c	32.9 ^c	2.93	48.2 ^b	26.9 ^c	74.7 ^c
Replicate								
1	**	**	n.s.	*	n.s.	**	n.s.	n.s.
2	77.0	78.3	9.8	27.7	2.98	48.9	27.7	78.0
	78.2	76.5	9.9	29.0	3.07	51.4	27.4	78.0

¹Any means in a group of factor means having the same superscript and are not significantly (P < 0.05) different from each other.

²Total of three measurements.

*Significant at P < 0.05.

**Significant at P < 0.01.

n.s. non-significant

were superior to the 114 kg market weight pigs in both characteristics.

In summary, the combined results of both replicates of Experiment 1 indicate that the HE diet improved ADG and FC as compared to the LE diet. However, when FC was converted to the basis of digestible energy per kg gain there were no differences in energetic efficiency between the pigs fed the HE and LE diets. Males gained faster than females, had a higher ADF and were less efficient in the conversion of feed to gain. Differences between breeding groups were found for ADG and FC with the Duroc and Hampshire-sired breeding groups being superior to the Yorkshire-sired groups.

Carcasses of pigs fed the HE diet were inferior to the carcasses of pigs fed the LE diet in total backfat thickness, ratio of loin to backfat, lean in the ham face, ham as a percent of carcass and ROP score. Females were superior to the males in all desirable carcass characteristics except dressing percentage where differences between sexes were not significant. In general, carcass leanness on the basis of the criteria measured, decreased from Hampshire to Duroc to Yorkshire-sired pigs. The Duroc and Hampshire-sired groups were superior to the Yorkshire-sired group in dressing percentage and loin area but were inferior in length. Length, loin area, dressing percentage and total backfat thickness increased with increases in carcass weight while ROP score and ham as a percent of the carcass decreased with increases in carcass weight.

Experiment 2 - Effects of Feeding System, Diet, Sex and Market Weight
on the Performance of the Hampshire-Sired Breeding
Group

1) Daily gain, Daily feed and Feed conversion

The means for ADG, ADF and FC for Experiment 2 and for Experiment 1, Replicate 2 are given in Table 6. Mean squares obtained by analysis of variance of the data are given in Appendix Table 2.

Feeding system significantly ($P < 0.01$) influenced ADG with the self-fed pigs from Experiment 2 gaining .07 kg per day more than did the limit-fed pigs from Experiment 1 in the over-all analysis.

Environment could have an effect as the pigs were fed in different barns so environment is confounded with method of feeding. However, a group of Hampshire $\times$ Yorkshire pigs were self-fed diets based on these same formulations in 1966 (Bowland, 1967) and performed similarly to the self-fed pigs discussed here. Diet also influenced ADG with the pigs fed the HE diet gaining more rapidly ($P < 0.01$) than the pigs fed the LE diet. Males grew faster ($P < 0.01$) than females. A significant ($P < 0.01$) market weight $\times$ feeding system interaction was present (Figure 2). The self-fed pigs at 114 kg market weight outgained the limit-fed pigs while no differences were noted at the 91 kg stage. This increased gain of self-fed pigs in the 114 kg market weight group may be a response to a change in environment since these pigs were moved to new quarters at an average weight of 63 kg. Some crippling was experienced in the New barn which may have inhibited the performance of the self-fed group.

Differences between feeding systems were also apparent for ADF

Table 6. Effects of feeding system, diet and sex on average daily gain, average daily feed and feed conversion of Hampshire-sired pigs - Experiment 2 vs Experiment 1, Replicate 2.

		68 kg				91 kg				114 kg				Total period			
		market weight				market weight				market weight							
		ADG	kg	ADF	kg	FC	kg/kg	ADG	kg	ADF	kg	FC	kg/kg	ADG	kg	ADF	kg
Feeding system		No. of pigs															
Diet	Limit	24	.68	1.77	2.73			.67	2.01	3.21	.61	2.12	3.56	.65	1.97	3.17	*
	Self	24	.71	2.13	3.16			.67	2.39	3.67	.78	2.62	3.34	.72	2.38	3.39	
	HE Limit	12	.79	1.81	2.44			.76	1.92	2.56	.68	2.06	3.04	.74	1.93	2.68	**
	Self	12	.84	2.00	2.38			.73	2.19	2.99	.83	2.38	2.69	.80	2.19	2.69	
LE	Limit	12	.58	1.73	3.01			.57	2.10	3.86	.53	2.18	4.07	.56	2.01	3.65	**
	Self	12	.57	2.26	3.93			.60	2.60	4.35	.72	2.86	4.00	.63	2.57	4.09	
Sex	M Limit	12	.70	1.89	2.81			.69	2.08	3.31	.63	2.27	3.65	.67	2.08	3.26	n.s.
	Self	12	.72	2.20	3.15			.70	2.46	3.54	.79	2.79	3.33	.74	2.48	3.34	**
	F Limit	12	.67	1.65	3.16			.64	1.95	3.10	.58	1.98	3.47	.63	1.86	3.07	n.s.
	Self	12	.70	2.06	3.16			.63	2.32	3.80	.76	2.45	3.36	.70	2.28	3.44	**

* Significant at P < 0.05.
** Significant at P < 0.01.
n.s. non-significant.

with the self-fed pigs consuming more feed ($P < 0.01$) per day than the limit-fed pigs. As gain is closely related to energy intake, the increased gain of the self-fed pigs is probably directly attributable to the increased feed and energy intake. A diet $\times$ feeding interaction (Figure 3) was present with the self-fed pigs on the LE diet consuming more feed ($P < 0.05$) per day than the limit-fed pigs on the LE diet while this difference was not apparent for pigs on the HE diet. This suggests that the limit-fed pigs on the LE diet may have experienced an energy restriction through inability to consume adequate feed in two 1 hr periods per day while the pigs fed the HE diet were not similarly restricted. Males consumed more feed per day ($P < 0.01$) than did the female pigs. Market weight also influenced ADF with the 68 kg market weight group consuming less ADF than did the 91 kg market weight group, who in turn consumed significantly less than the 114 kg market weight group ($P < 0.01$).

The feeding system affected FC with the limit-fed pigs being more efficient ($P < 0.05$) converters of feed to gain. Similarly, the pigs fed the HE diet were more efficient converters of feed to gain than were those fed the LE diet (Figure 4). When transferred to a digestible energy basis (Table 7), there was a difference in energy conversion between pigs fed the two diets. A feeding $\times$ market weight interaction (Figure 5) was significant for FC. The self-fed group became more efficient converters of feed to gain than were the limit-fed group at the 114 kg market weight. This improvement in FC was probably due to the improvement in ADG when the environment was changed.

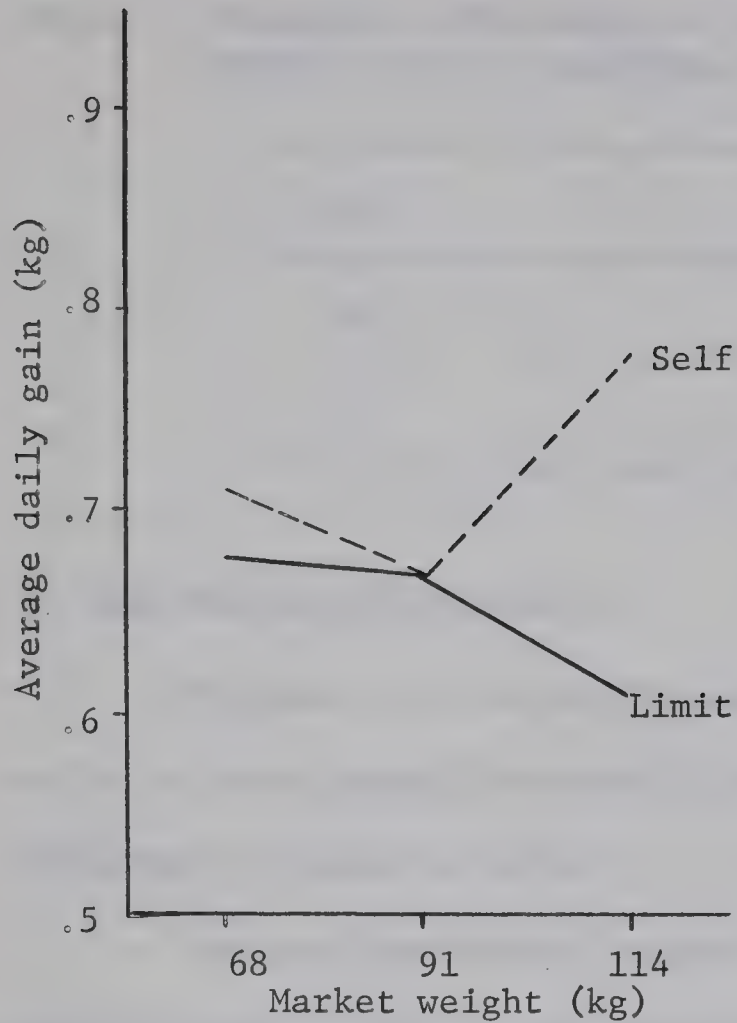


Figure 2. Interaction of feeding system × market weight on average daily gain - Experiment 2.

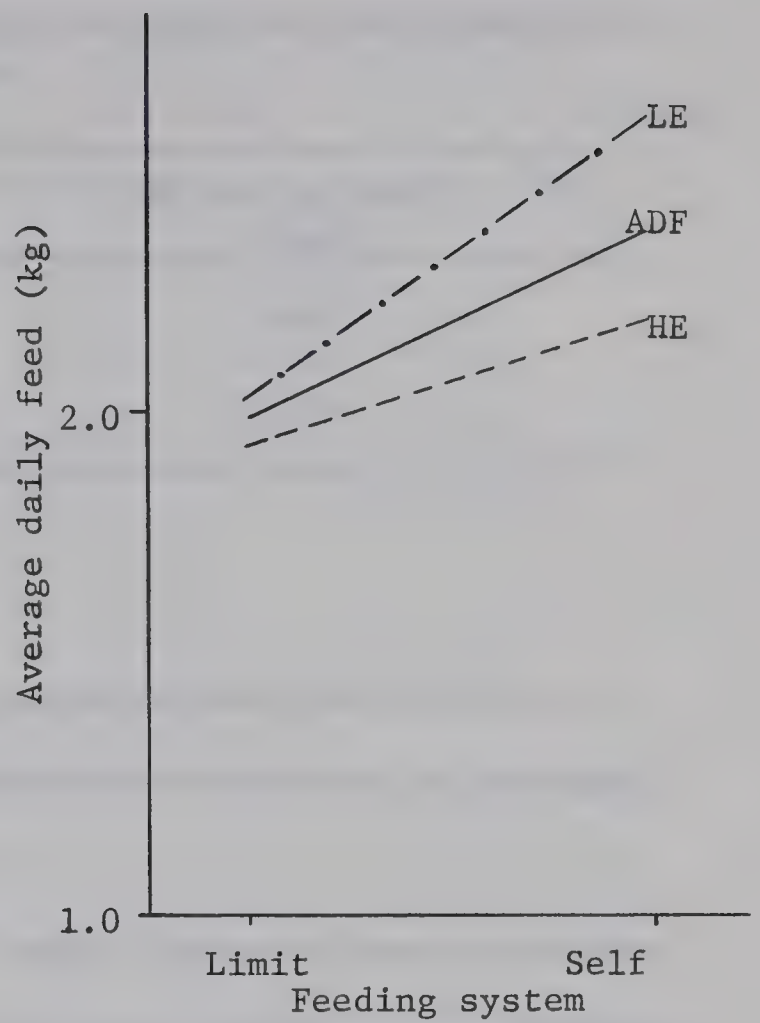


Figure 3. Interaction of diet × feeding system on average daily feed - Experiment 2.

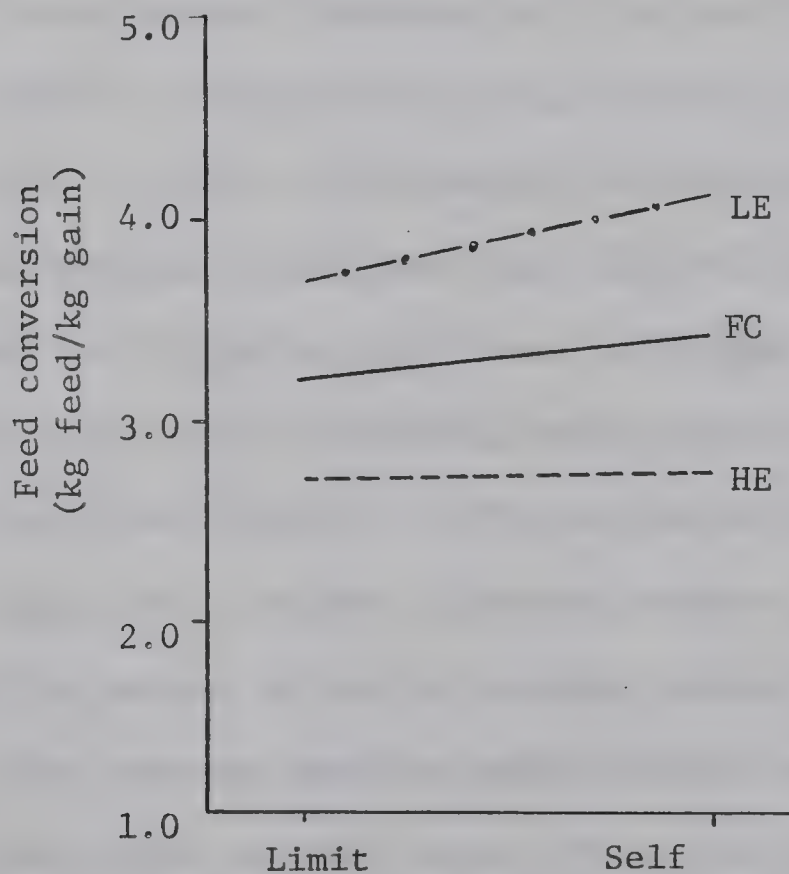


Figure 4. Interaction of diet × feeding system on feed conversion - Experiment 2.

Table 7. Energetic efficiency of pigs fed high and low digestible energy diets - Experiment 2.

Diet	DE per kg gain (Mcal)
HE	9.82
LE	11.28

2) Carcass characteristics

The means for carcass characteristics are given in Table 8 while the mean squares obtained by analysis of variance of the data are given in Appendix Table 2.

Dressing percentage, carcass length, percent lean in the ham face and ham as a percent of carcass were not significantly affected by the feeding system. However, differences between feeding systems were found for total backfat thickness with the self-fed group being inferior ($P < 0.01$) to the limit-fed group in this parameter. Loin area and the ratio of loin to total backfat thickness were also influenced by the feeding system with the limit-fed pigs having larger loin areas and higher ratios of loin to backfat ($P < 0.05$). ROP score was influenced by the feeding system with the limit-fed pigs having a higher ROP score ($P < 0.05$) at the 91 kg and 114 kg market weight (Figure 6). Backfat thickness assumes particular importance with the advent of the new grading system introduced in January, 1969. The previous grading system did not accurately compensate for individual carcass value. There was also a considerable variation in the yield of lean meat within the same grade.

Fredeen et al.(1964) demonstrated that total backfat thickness (maximum depth of shoulder plus maximum depth of loin) was a reliable indicator of yield of lean meat. This factor and warm carcass weight have been incorporated into the new carcass valuation system. The evidence here suggests that the limit-feeding system would be advantageous with regard to backfat measurements and hence with regard to carcass returns. No economic comparisons can be made, here, however, as to the other factors of gain, feed conversion and dressing percentage which also influence net returns from market pigs.

In summary, the evidence from Experiment 2 indicates that the feeding system has a significant effect on ADG, ADF and FC with the self-fed pigs having a significantly higher ADG and ADF. Pigs fed the HE diet gained faster ($P \leq 0.01$) than did the pigs fed the LE diet. On the HE diet there was no difference in FC between the limit-fed and self-fed pigs while on the LE diet the self-fed pigs were less efficient converters of feed to gain than were the limit-fed pigs. The feeding system also affected total backfat thickness, loin area, ratio of loin to backfat and ROP score with the self-fed pigs being inferior to the limit-fed pigs in these carcass characteristics. The method of limit-feeding could also influence the results obtained as a time restriction could have a bearing on the performance of pigs so fed.

Table 8. Effects of feeding system, diet, sex and market weight on certain carcass characteristics of Hampshire-sired pigs - Experiment 2 vs Experiment 1, Replicate 2.

		Dressing %	Length cm	Total ¹ backfat cm	Loin area sq.cm	Ratio loin to backfat	Lean in ham face %	Ham carcass %	ROP score
Limit & Self-feeding		78.1	76.0	9.8	29.7	3.17	52.3	27.2	78.0
Diet	HE	**	n.s.	**	n.s.	**	**	**	**
	Limit		75.9		31.7				
	Self	78.7	75.6	11.2	27.0	3.06	50.8	26.8	77.1
	LE	77.2	75.9	8.4	29.9	2.47	50.8	26.2	75.8
Sex	Limit	76.7	76.4	9.2	30.2	3.68	54.3	28.0	78.0
	Self	n.s.	**	**	*	**	**	**	**
	M								
	Limit	78.5	75.5	10.3	29.7	2.92	50.2	26.8	76.7
	Self	77.4	75.0	11.4	26.8	2.44	49.8	26.6	75.2
	Limit	78.6	76.3	8.6	31.9	3.82	54.8	28.1	80.4
	Self	77.9	77.0	9.0	30.4	3.50	54.5	27.2	79.6
Market weight		**	**	**	**	n.s	**	**	**
68 kg	Limit								
	Self	74.9	70.8	7.9	25.9	3.40	54.0	27.6	81.3
91 kg	Limit	77.2	70.4	8.3	25.9	3.26	55.0	28.2	81.7
	Self	77.9	76.0	9.2	30.3	3.41	52.4	27.9	79.0
114 kg	Limit	79.2	76.3	10.2	28.2	2.89	51.7	27.3	77.5
	Self	82.9	81.0	11.2	36.2	3.30	51.2	26.8	75.3
Limit-feeding	Limit	76.6	81.3	12.1	31.8	2.76	49.7	25.2	73.1
	Self	n.s.	n.s.	**	*	*	n.s.	n.s.	*
Self-feeding		78.6	75.9	9.4	30.8	3.37	52.5	27.4	78.5
Self-feeding		77.7	76.0	10.2	28.6	2.97	52.2	26.9	77.4

¹Total of three measurements.

* Significant at P < 0.05.

** Significant at P < 0.01.

n.s. non-significant.

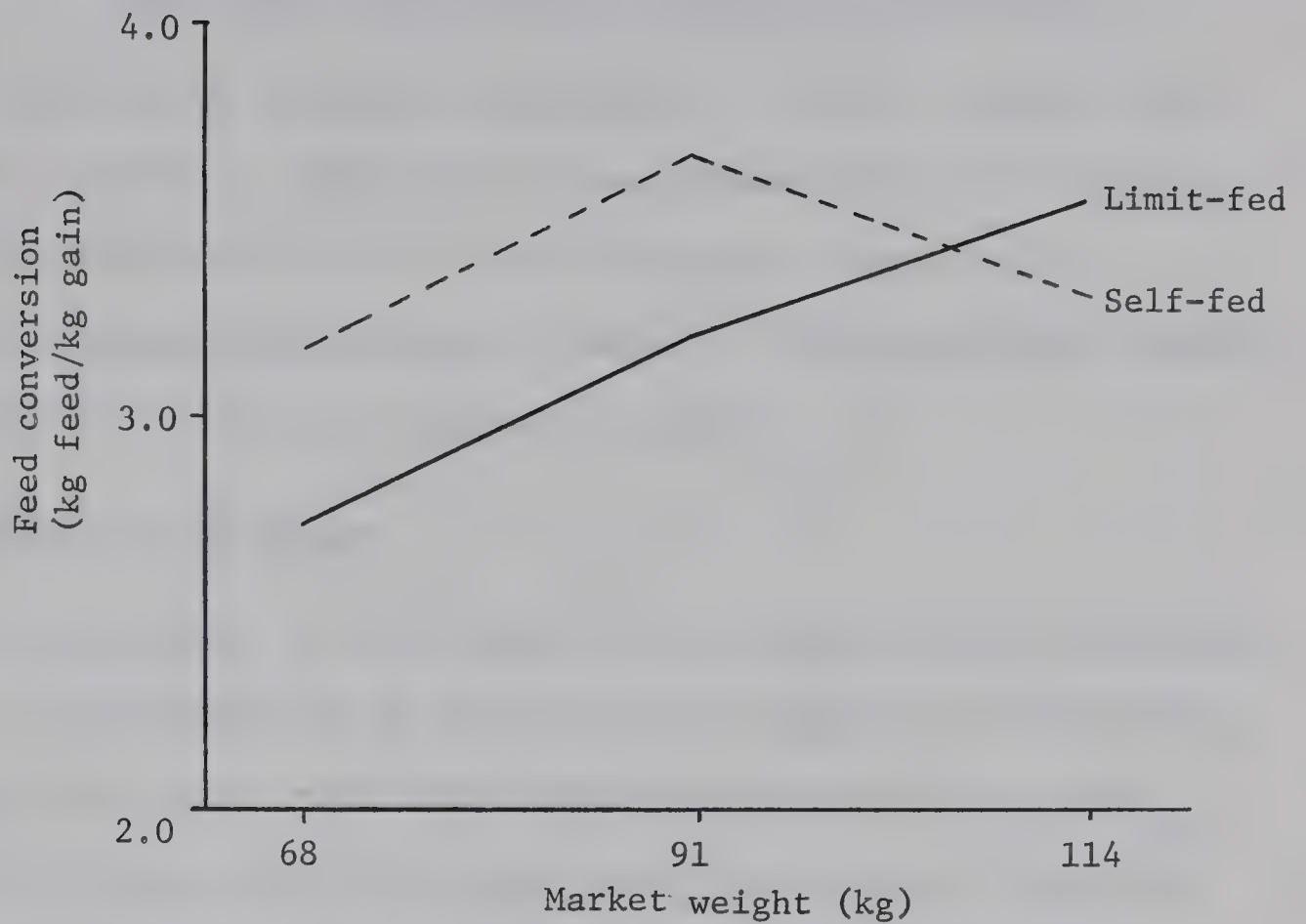


Figure 5. Interaction of feeding system $\times$ market weight on feed conversion - Experiment 2.

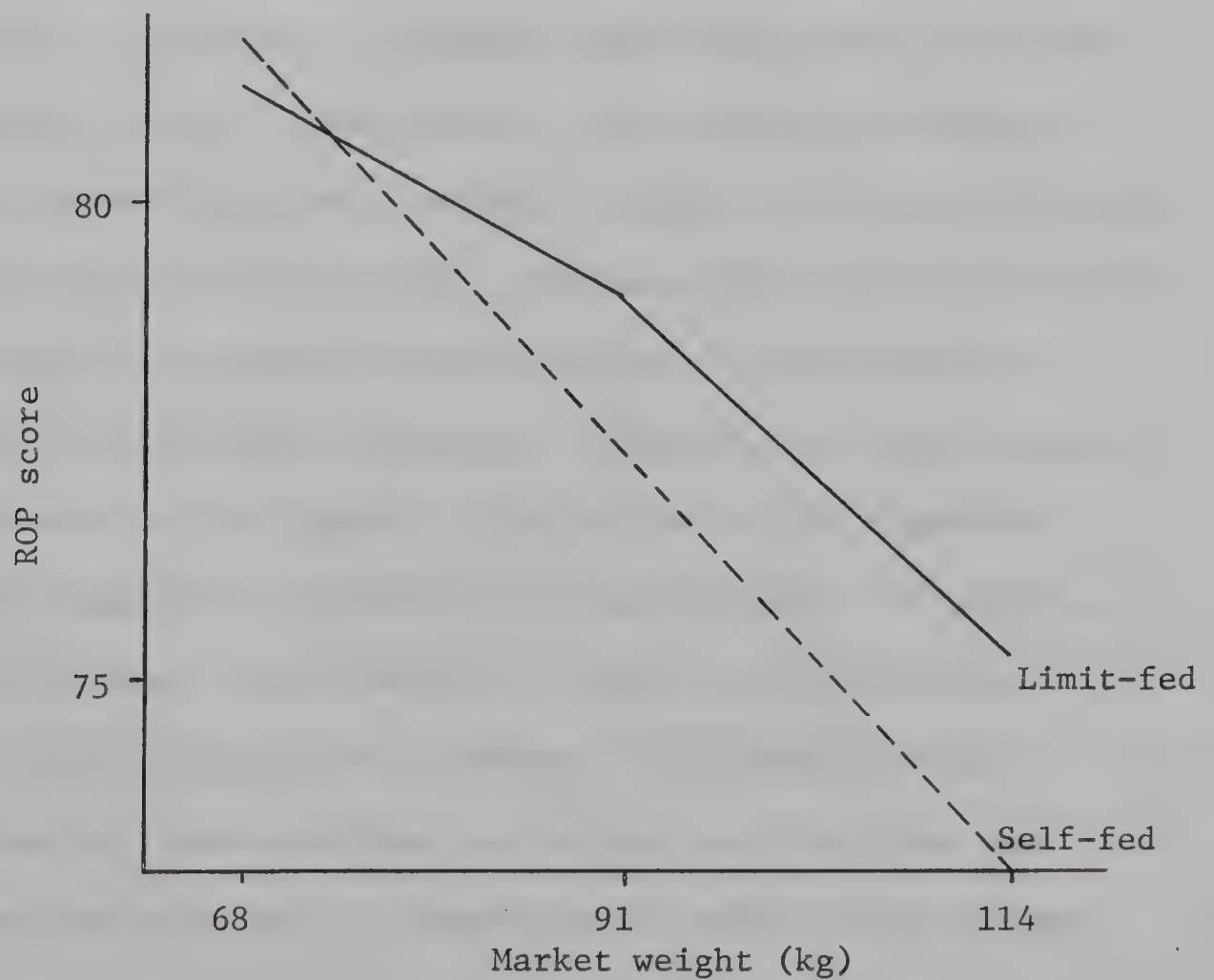


Figure 6. Interaction of feeding system $\times$ market weight on ROP score - Experiment 3.

Experiment 3 - Effects of Diet, Sex and Breeding Group on Nitrogen and Energy Digestibility and Nitrogen Retention

Means for the apparent digestibility of energy, metabolizable energy as a percent of digestible energy, digestibility of nitrogen, nitrogen retention and for the ratio of nitrogen retention to digestible nitrogen are presented in Table 9. The statistical analysis of these data is presented in Appendix Table 3.

1) Digestibility of Energy

The percentage of both digestible and metabolizable energy were higher ($P < 0.01$) when the HE diet was fed as compared to the LE diet. The pigs in the second replicate digested an average of 8.7% more ($P < 0.01$) of the energy in the diets than was digested by those in replicate 1. It was noted that a difference in feed consumption occurred between replicates 1 and 2 (Table 10) in that the animals fed the LE diet in replicate 1 consumed significantly more feed than the pigs fed the LE diet in replicate 2. Pigs fed the HE diet in replicate 1 consumed less feed than did the pigs in replicate 2 though this difference was non-significant. McDonald, Edwards and Greenhalgh (1966) state that an increase in the quantity of food eaten by an animal causes a faster rate of passage of digesta, and thus a shorter period of exposure of the digesta to the action of the digestive enzymes, which results in a reduction in digestibility. Therefore, the difference between replicates may be partly attributable to differences in feed consumption. However, a difference in feed consumption was only observed when the LE diet was fed. Sex and breeding group had no effect on digestible or metabolizable energy.

Metabolizable energy was a relatively constant proportion (96%) of digestible energy. This ratio did not vary significantly between diets, sex, breeding groups or replicates.

2) Digestibility of Nitrogen

Diet had a significant ($P < 0.01$) influence on the digestibility of nitrogen with the HE diet having an increased digestible nitrogen when compared to the LE diet. Lowrey et al. (1958) found that fat added to the diet of growing pigs resulted in increased digestibility of protein. Kuryvial and Bowland (1962) also found that an increase in the energy level of the diet increased the digestibility of protein. Furthermore, Likuski et al. (1961) reported an increase in percentage of digestible protein with high protein levels.

Sex and breeding group had no effect on digestible protein. A replicate $\times$ diet interaction (Table 11) was present with the pigs fed the LE diet in replicate 2 having higher digestible nitrogen values than did the pigs fed the LE diet in replicate 1. This difference in digestible nitrogen may also be partly attributed to differences in feed consumption discussed previously.

3) Nitrogen Retention

Diet did not have a significant effect on nitrogen retention. Previous workers (Kuryvial and Bowland, 1962; and Lowrey et al., 1963) have observed that increased dietary energy had no effect on nitrogen retention. Nitrogen retention was not affected by either sex or breeding group.

Table 9. Effect of diet, sex, breeding group and replicate on digestible and metabolizable energy, digestible nitrogen and nitrogen retention - Experiment 3.

	DE	ME	ME/DE	Digest- ible N	N reten- tion	N retention digestible N
Replicate 1 & 2	75.3	72.4	96.2	80.4	37.6	47.0
Diet	**	**		**		*
HE	84.6	81.4	96.2	87.5	37.6	42.8
LE	65.9	63.4	96.2	73.2	37.7	51.1
Sex						
M	75.2	72.4	96.0	80.3	35.9	44.4
F	75.3	72.5	96.3	80.4	39.3	49.6
Breeding group						
Duroc	76.2	73.3	96.2	80.1	35.2	44.8
Hampshire	75.2	72.2	95.9	79.2	35.2	43.7
Yorkshire	74.4	71.7	96.4	81.8	42.5	52.4
Replicate	**	**		**		
1	70.9	68.3	96.2	76.9	38.7	50.1
2	79.6	76.5	96.1	83.8	36.6	43.8

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

Table 10. Total feed consumption (g/day) of high and low energy diets in replicate 1 and 2 - Experiment 3.

Diet	Replicate 1	Replicate 2
High energy	4884	5038
Low energy	6210	4660

Table 11. Replicate and diet effects on digestibility of nitrogen (%).

Diet	Replicate 1	Replicate 2
High energy	86.6	88.4
Low energy	67.2	79.2

4) Nitrogen Retention/Digestible Nitrogen

A lower percentage ($P < 0.05$) of dietary nitrogen was retained on the HE diet than on the LE diet. This difference may be associated with the different protein levels in the HE and LE diets. Sex, breeding group and replicate did not affect the ratio of nitrogen retained to nitrogen digested.

In summary, the experimental evidence indicates that the diet containing the higher level of digestible energy had a higher percentage of digestible nitrogen. Sex or breeding group did not affect the digestibility of energy or nitrogen. Nitrogen retention was not affected by diet, sex or breeding group.

GENERAL SUMMARY AND CONCLUSIONS

The following results were obtained when two diets were fed to two sexes, three breeding groups and the pigs marketed at three market weights;

Rate of Gain, Feed Consumption and Feed Conversion

ADG in pigs was increased with the use of a HE diet containing 3650 kcal DE/kg diet compared to a LE diet containing 2750 kcal DE/kg diet. Males had a significantly higher ADG on the HE diet than did the females but no differences between sexes occurred on the LE diet. A difference in rate of gain was also found between breeding groups with the Duroc and Hampshire-sired pigs gaining more rapidly than the Yorkshire-sired group. Feeding system also affected ADG with the self-fed pigs gaining more rapidly than the limit-fed pigs. This difference in ADG was particularly evident at the 114 kg market weight. This influence of weight to market may be partially explained by the change in environment that these pigs experienced.

ADF was not affected by diet or breeding group. Thus the pigs were unable to adjust their feed intake to compensate for the lower digestible energy in the LE diet. However, a significant diet $\times$ breeding group interaction showed that the Duroc-sired pigs consumed more feed when fed the HE diet as compared to the LE diet. Feeding system also affected ADF with the self-fed group consuming more feed at each market weight and in the over-all period than was consumed by the pigs fed for two 1 hr periods per day.

Feed conversion was improved in pigs fed the HE diet as compared

to the LE diet. When compared on the basis of digestible energy conversion in Experiment 1, no differences in conversion between the HE and LE diets were noted. However, under self-feeding conditions, Experiment 2, the pigs fed the HE diet were more efficient converters of digestible energy to gain than were pigs fed the LE diet. Females were superior to the males in FC when the LE diet was fed but no difference in FC existed between sexes when the HE diet was fed. Furthermore the Duroc and Hampshire-sired groups were more efficient converters of feed to gain than were the Yorkshire-sired group.

Carcass Characteristics

Carcasses from pigs fed the HE diet had an increased dressing percentage. However, the HE diet adversely affected total backfat thickness, ratio of loin to backfat, lean in ham face, ham as a percent of carcass and ROP score.

Female carcasses were superior to the male carcasses in all parameters except dressing percentage where differences were non-significant.

The Duroc and Hampshire-sired breeding groups were superior to the Yorkshire-sired group in dressing percentage but were inferior in carcass length. The Hampshire-sired group was superior to the Duroc and Yorkshire-sired groups in total backfat thickness and ratio of loin to total backfat. The Hampshire-sired group had a larger loin area than did the Duroc-sired group, who in turn were superior to the Yorkshire-sired group. The Hampshire-sired group also had a higher percent of lean in the ham face than did the Yorkshire-sired group.

Dressing percentage, length, total backfat thickness and loin area increased with increased market weight. The lean in the ham face, ham as a percent of carcass and ROP score tended to decrease with increased carcass weights.

The feeding system influenced carcass characteristics in that the limit-fed pigs were superior to the self-fed pigs in backfat thickness, loin area, ratio of loin to backfat thickness and ROP score.

Energy and Nitrogen Digestibility and Nitrogen Retention

The results of the present study indicate that the energy level in the diet significantly affected the digestibility of energy. This result would be anticipated on the basis of experimental design. Energy digestibility was not significantly influenced by sex or breeding group.

Apparent digestibility of nitrogen was increased by feeding a diet containing a higher level of energy but not by sex or breeding group. Energy levels, sex and breeding group had no effect on nitrogen retention.

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Appendix Table 1. Mean squares for average daily gain, average daily feed, feed conversion and carcass measurements - Experiment 1.

	d.f. ¹	ADG	ADF	FC	Dressing %	Length	Total fat	Loin area	Ratio loin to backfat	Lean in ham face	Ham/ carcass	ROP score
Replicate (R)	1	.006	.006	.549*	44.69**	123.46**	.35	64.9*	.063	217.8**	3.048	.02
Sex (S)	1	.032**	1.115**	1.104**	.99	30.98*	64.00**	372.3**	2.646**	857.4**	12.954**	272.97**
RS	1	.011	.000	.320	17.96*	35.50**	1.95	9.1	.003	8.9	.052	2.68
Breeding group(B)	2	.038**	.001	.942**	31.39**	181.28**	4.95*	182.9**	.470**	122.1*	.185	8.80
RB	2	.006	.061	.012	1.60	7.46	.66	.3	.019	33.0	1.430	.17
SB	2	.005	.029	.093	3.88	.24	.70	26.4	.240*	29.0	5.419*	6.39
RSB	2	.001	.002	.119	.24	.59	.55	2.5	.020	.9	1.186	2.40
Diet (D)	1	1.417**	.021	28.864**	44.16**	2.80	117.42**	43.9	2.396**	518.6**	45.080**	404.68**
RD	1	.000	.101	.696*	36.38**	.91	2.58	16.4	.009	8.0	.755	.17
SD	1	.038**	.046	.657*	5.90	1.67	.15	8.6	.185	21.3	1.434	.64
RSD	1	.001	.034	.115	1.64	.01	.95	.2	.002	25.2	.028	.06
BD	2	.012	.184**	.216	.46	10.78	2.20	44.3*	.027	45.7	.209	1.65
RBD	2	.005	.019	.019	.47	1.78	.73	14.1	.023	54.7	.939	3.59
SBD	2	.003	.018	.077	.99	5.80	6.62**	25.3	.030	18.5	2.227	8.07
Market weight (M)	2	.010	2.748**	4.171**	319.52	1626.50**	149.70**	1065.2**	.042	223.2**	26.671**	497.43**
RM	2	.013*	.077	.070	7.51	1.89	1.56	15.5	.015	38.4	1.670	1.13
SM	2	.001	.010	.134	6.28	12.53	3.75	11.9	.089	8.1	.519	8.43
RSM	2	.003	.042	.266	6.62	6.27	.22	21.7	.038	28.4	.798	4.77
BM	4	.008	.017	.120	11.96*	5.79	4.14*	9.2	.078	32.6	1.669	8.96
RBM	4	.003	.014	.155	12.68**	6.35	.28	15.0	.018	9.8	2.942	2.05
SBM	4	.007	.008	.185	6.14	6.42	3.06	6.0	.050	83.8	.850	5.42
DM	2	.017	.140	.015	3.69	1.32	1.71	9.2	.005	21.7	1.293	5.13
RDM	2	.006	.054	.357*	9.07	20.79*	1.59	27.3	.094	20.5	1.145	6.94
SDM	2	.004	.049	.642**	7.09	15.72	1.53	1.2	.012	5.7	.194	3.48
BDM	4	.003	.035	.098	6.02	2.28	1.07	9.7	.026	10.9	1.779	.81
Error	92	.004	.029	.102	3.47	5.13	1.26	13.0	.074	33.3	1.455	5.65

¹Five pigs died during the experiment. Two carcasses were also lost. Thus error d.f. is reduced by five for the growth and feed utilization data and error d.f. is reduced by seven for carcass data.

Appendix Table 2. Mean squares for average daily gain, average daily feed, feed conversion and carcass measurements - Experiment 2 vs Experiment 1, Replicate 2.

	d.f. ¹	ADG	ADF	FC	Dressing %	Length	Total fat	Loin area	Ratio loin to backfat	Lean in ham face	Ham/carcass	ROP score
Feeding system(F)	1	.049**	2.042**	.612*	9.53	.163	6.97**	57.8*	.30*	1.54	3.23	15.30*
Sex (S)	1	.022**	.555**	.021	1.24	22.36**	49.54**	99.7*	1.77**	259.14**	11.28**	195.13**
FS	1	.000	.001	.244	.37	4.68	.91	5.8	.01	.01	1.32	1.53
Diet (D)	1	.367**	.626**	16.851**	64.38**	2.04	47.49**	6.0	1.20**	120.81**	19.62**	114.52**
FD	1	.000	.282*	.576*	1.25	2.26	.05	76.5*	.07	1.52	.15	.44
SD	1	.006	.039	.007	.10	2.48	2.84	13.3	.36**	33.48	.01	7.91
FSD	1	.057**	.031	1.003**	6.85	9.71*	.19	52.5	.08	16.20	.98	4.14
Market weight (M)	2	.004	.727**	1.359**	54.86**	447.37**	51.17**	267.4**	.05	67.49**	17.17**	214.52**
FM	2	.034**	.024	.581**	89.61**	.74	.38	20.1	.03	6.14	4.72*	7.43
SM	2	.001	.033	.014	4.72	.08	2.62*	13.6	.03	46.49**	.43	5.85
FSM	2	.000	.006	.026	.87	.62	2.98*	47.4	.01	2.45	1.09	2.82
DM	2	.013	.058	.076	5.90	8.57*	.39	27.7	.04	4.52	.89	.24
FDM	2	.004	.005	.231	2.89	2.04	1.46	29.2	.02	8.74	.83	.62
SDM	2	.004	.000	.062	6.81	4.93	.14	7.8	.07	19.20	1.90	.21
Error	26	.004	.038	.089	2.35	2.10	.76	14.1	.05	8.93	.98	2.94

¹Three pigs died during the growth period and no carcass information was obtained on still another, so error d.f. is reduced to 23 for growth and feed data and 22 for carcass characteristics.

Appendix Table 3. Mean squares obtained by analysis of variance of digestibility data - Experiment 3.

	d.f.	DE	ME	ME/ DE	Digest- ible N	N reten- tion	<u>N retention</u> <u>digestible</u> N
Replicate (R)	1	901.3**	817.6**	15.2	571.3**	56.3	475.7
Sex (S)	1	.3	1.1	93.5	.1	138.0	321.9
RS	1	95.8	114.4	285.2	3.6	309.1	546.0
Breeding group (B)	2	12.8	11.1	89.6	26.9	283.5	359.9
RB	2	14.6	17.1	88.9	24.5	47.4	68.4
SB	2	18.0	17.6	22.1	75.0	9.4	73.7
RSB	2	46.5	47.8	57.4	34.7	36.7	110.6
Diet (D)	1	4218.7**	3897.0**	2.1	2456.7**	.1	834.2*
RD	1	94.6	65.1	275.5	311.1**	20.8	20.9
SD	1	22.1	16.2	72.5	3.3	33.0	121.9
RSD	1	28.2	11.1	379.7	2.3	35.7	19.6
BD	2	2.7	5.3	195.9	42.4	126.2	192.8
RBD	2	48.0	67.4	552.3*	85.0	188.7	169.1
SBD	2	28.2	38.9	315.0	57.8	675.1**	908.4*
Error	26	34.5	35.2	113.4	57.0	117.4	148.0

* Significant at $P < 0.05$.

** Significant at $P < 0.01$.

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